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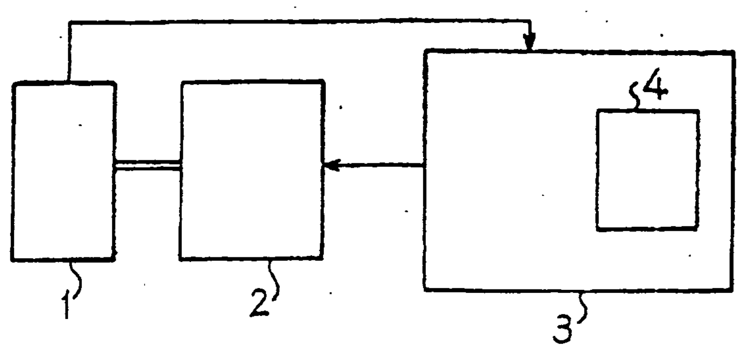
(54) **System for positioning a transducer.**

(57) The present invention proposes a system for positioning a control object such as a magnetic head(1;11)by moving at a high speed such object (1;11)without generation of vibration. An actuator loading the magnetic head (1;11)and an arithmetic control means (3;18)for controlling a drive motor (2;12)of the actuator based on result of digital arithmetics are comprised. The arithmetic control means (3;18)compute target position, target velocity and target acceleration of each sample period in accordance with polynomials indicating predetermined target position, target velocity and target acceleration, output at least one error between the target position, target velocity as a result of arithmetic and position, velocity of the magnetic head (1;11)at every sample period and control the drive motor (2;12)with an added output of the such position error or speed error and target acceleration as a result of the arithmetic.

FIG. 4



SYSTEM FOR POSITIONING A TRANSDUCER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a system for positioning at high speed a transducer such as magnetic head, optical head and print head etc. and more specifically to a positioning control system which has improved accuracy of positioning.

2. Description of the Prior Art

A storage apparatus such as magnetic disk apparatus and optical disk apparatus executes so-called head seek operation for moving the head to the target track position from the current track position on the disk by controlling an actuator mounting the head. When the head is positioned to the designated target track position, data writing or reading operation is carried out trough the head. Moreover, even in a recording apparatus such as serial printer, X-Y plotter, etc., recording such as printing is carried out by moving and positioning the print head to the target position from the current position.

Fig. 1 is a sectional view indicating schematic structure of an ordinary magnetic disk apparatus of the prior art providing rotary actuator.

In Fig. 1, an enclosure 111 supports rotatably, for example, three sheets of magnetic disks 112 through a spindle 113 and these disks 112 are rotated at a constant speed, for example, of 3600 rpm with a spindle motor 114. Moreover, the magnetic head 115 is attached to a head arm 117 through a support spring means 116 and is positioned to the designated track of the magnetic disk 112. The rotary actuator is composed of a rotary member 118 which fixes the head arm 117 and is rotatably supported by the enclosure 111 and a positioning motor for rotating the rotary member, for example, a voice coil motor 119, and rotates the magnetic head 115 for predetermined angle around the rotating axis of rotating member 118.

A magnetic disk apparatus for high density recording uses a closed loop servo control means for controlling such actuator. This closed loop servo control means detects the current position of magnetic head from the original position thereof by reading servo information on the magnetic disk with a magnetic head, also calculates distance to the designated track position from the current position, drives the positioning motor based on such distance and positions the magnetic head to the designated track. Fig. 2 schematically shows an example of such servo control system.

In Fig. 2, 115A denotes servo head for positioning; 115B, data read/write head; 121, rotary actuator; 122, 123, amplifier; 124, demodulator for demodulation servo signal; 125, AD converter; 126, DA converter; 127, read/write control circuit; 128, motor control circuit; 129, main controller consisting of microprocessor. The same reference numerals are used for indicating the disk rotating system and head positioning system. This servo control system is formed by a closed loop of servo head 115A - amplifier 122 - demodulator 124 - AD converter 125 - main controller 129 - DA converter 126 - amplifier 123 - rotary actuator 121. The functions of these elements are already known and only the control of actuator in relation to the present invention will be explained here.

The main controller 129 comprises a memory to store tabulated data indicating a curve of target velocity corresponding to the moving distance of head. In concrete, a target velocity curve which is calculated on the off-line basis and is shown in Fig. 3, is used as a function of the number of tracks in the distance up to the target track position from the current track position. This target speed curve shows the deceleration characteristic for stopping the head at the target track position from a certain velocity thereof and the actuator is controlled corresponding to error between the actual velocity of head and the target velocity curve. Therefore, since there is a large velocity error when the head seeking operation is started, when the voice coil motor of actuator is driven with maximum capability of the driving force and the actual velocity of head coincides with the target velocity curve, the deceleration control is then carried out in accordance with the target velocity curve.

Such control is generally realized with a structure introducing the analog circuit but the structure which realizes such control with digital circuit is also proposed.

The positioning control in such prior art realizes control of head by giving the target velocity curve which indicates the deceleration characteristic and basically does not conduct control of acceleration. Accordingly, the high speed seek operation requires supply of heavy current to the voice coil motor of

actuator at the time of starting seek and coincidence between acutal velocity and target velocity curve within a short period of time, and also requires large change of drive current.
Moreover, change of drive current also becomes large when acceleration mode is switched to the deceleration mode. Therefore, harmonics in the drive current increase deriving vibration due to resonance of mechanical part of actuator including magnetic head and decrease the accuracy of the head positioning. Therefore, it has been difficult to realize the high speed seek operation

For this condition, it is thought to control the head velocity for both acceleration and deceleration of seek but it is difficult to realize such control because the analog circuit structure is complicated. Moreover, it can also be thought to realize such control with digital circuit, but it is far from easy to realize such control without derivation of vibration even when the head speed is controlled for both acceleration and deceleration.

As a system for controlling speed and acceleration of head in both acceleration and deceleration of seek operation in order to prevent the problem explained above, namely vibration and noise of actuator means in the seek operation of head, two kinds of methods, the U.S. Patent No. 4,796,112 by M. Mizukami et. al. and the U.S. Patent No. 4,937,689 by Jay. S. Sunnyvale et. al. are proposed. These methods employ the trapezoidal wave as the acceleration and deceleration current (acceleration) in order to suppress vibration. Therefore, these methods are required to determine the shape of trapezoidal acceleration in accordance with each seek stroke. In other words, the times until the preset trapezoidal acceleration reaches the maximum value and minimum value and the time for switching the acceleration to deceleration must be set in detail.
Particularly it is essential in the U.S. Patent No. 4,796,112 to set the ratio of upper side and bottom side of trapezoidal wave in accordance with the seek stroke. Accordingly, these methods have the disadvantage that the circuit structure or algorithm are very complicated for both analog and digital circuits.

SUMMARY OF THE INVENTION

It is a main object of the present invention to provide a high speed positioning system for realizing acceleration and deceleration controls of actuator without generation of vibration in the transducer such as magnetic head, optical head and print head apparatus.

It is another object of the present invention to provide a positioning control system for transducer by simple algorithm utilizing digital arithmetic circuit.

Briefly, the present invention is characterized by controlling position, velocity and acceleration of the transducer minimizing a cost function by indicating such state values as the polynomials of the time.

In more detail, the present invention comprises a drive such as actuator for realizing positioning by moving the transducer such as magnetic head and an arithmetic controller for controlling such driver with digital arithmetics. The target position, target velocity and target acceleration are indicated as the polynomials of time on the basis of the acceleration and deceleration patterns which minimize square integration value of differential value of acceleration of the transducer and the target position, target velocity and target acceleration of each time are computed in the arithmetic controller using such polynomials. This arithmetic controller outputs of at least one error between the target position, target velocity as the result of arithmetics and position, velocity of each sample period of the transducer, adds such position error or velocity error and the target acceleration as a result of such arithmetic, controls the driver with this added signal and thereby positions the transducer to the target position.

Other objects and characteristics of the present invention will be well unterstood from explanation about a preferred embodiment described with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic sectional view of a conventional magnetic disk apparatus comprising an ordinary rotary actuator;

Fig. 2 and Fig. 3 are diagrams for explaining servo control for head positioning in the magnetic disk apparatus of the prior art;

Fig. 4 is a diagram for explaining the basic structure of the present invention;

Figs. 5(A), 5(B), 5(C) are a block diagram for indicating a structure for head positioning control in the magnetic disk apparatus to which the present invention is applied;

Fig. 6 is a flowchart for explaining operation of an embodiment of the present invention shown in Fig. 5;

Fig. 7 is a diagram for explaining position, velocity and acceleration of magnetic head;

Fig. 8 shows a relation curve between the seek distance and inverse value of seek time of the magnetic head;

Fig. 9 shows a relation curve between normalized distance and normalized time; and
Fig. 10 is an acceleration characteristic curve of magnetic head.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Prior to explanation about a preferred embodiment of the present invention, the basic structure of the present invention will be first explained with reference to Fig. 4.

Namely, in Fig. 4, numeral 1 denotes transducer (apparatus to be controlled) such as magnetic head, optical head and print head, etc.; 2, driver for moving the transducer 1 for the positioning; 3, arithmetic controller for controlling the driver 2 with digital arithmetics; 4, data table consisting of memory. In the present invention, the target position, target velocity and target acceleration are indicated with polynomials of time based on the basis of acceleration and deceleration patterns which minimize the square integral value of differential value of the acceleration of the transducer 1 and controls the driver 2 in accordance with difference between the arithmetic result of each sample time and the arithmetic controller 3 computes the target position, target velocity and target acceleration of each sample period using such polynomials, outputs at least one error between target position, target velocity as a result of such arithmetic and position, velocity of each sample period of transducer 1, moreover adds the position error or velocity error and the target acceleration as a result of such arithmetic and controls the driver 2 with the added output.

Namely, the acceleration and deceleration profiles are set for minimizing square value of differential value of acceleration. In this case, the cost function J is expressed by the following equation.

$$J = \int u^2 dt \quad (1)$$

Where, when a drive current of the driver 2 is assumed as i, u is defined as u = di/dt and the drive current i corresponds to acceleration. The state equation is expressed as

$$X = AX + Bu \quad (2)$$

Here, A, B and X are defined as follows when the mass of transducer 1 is m.

$$\left. \begin{aligned} A &= \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \\ B &= \begin{bmatrix} 0 \\ 0 \\ B\ell / m \end{bmatrix} \end{aligned} \right\} \cdots (3)$$

The boundary condition is as follows when the designed seek time is assumed as T and the moving distance as a.

$$\left.\begin{aligned} X(0) &= \begin{pmatrix} a \\ 0 \\ 0 \end{pmatrix} \\ X(T) &= \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \end{aligned}\right\} \quad \cdots\cdots (4)$$

Therefore, the target position X_1, target velocity X_2 and target acceleration X_3 of the positioning control for minimizing cost function J is indicated as follows.

X_1 = -60a $0.1(t/T)^5 - 0.25(t/T)^4 + (1/6)(t/T)^3$ (5)
X_1 = -60a $0.5(t/T)^4 - (t/T)^3 + 0.5(t/T)^2 /T$ (6)
X_3 = -60a $2(t/T)^3 - 3(t/T)^2 + (t/T) /T^2$ (7)

The equations (5), (6) and (7) are computed in the arithmetic controller 3 for each sample period (Ts) and the driver 2 is controlled to follow up the position, velocity and acceleration of the actual transducer.

Since the gain of target velocity and gain of target acceleration are indicated in the equations (6), (7) as

$$\left.\begin{aligned} &-60a/T \\ &-60a/T^2 \end{aligned}\right\} \quad \cdots\cdots (8)$$

the designed seek time T corresponding to the seek distance a or its inverse value 1/T or ratio (Ts/T) is previously stored in the data table 4 and the target velocity gain and target acceleration gain can be computed using the values obtained by retrieving the data table based on the moving distance a immediately before the seek operation.

The time t from start of seek operation of transducer 1 is normalized by the designed seek time T and the target acceleration, target velocity and target position can be computed using this normalized time t/T.

The normalized position x/a of each sample period can be computed by the distance X from start of the seek operation of transducer 1 and the designed seek distance. Then the normalizing time can also be obtained by retrieving another data table that stores relationship between the normalized position x/a and normalized time t/T.

A preferred embodiment of the present invention in accordance with such basic structure will be explained in detail.

Figs. 5(A), (B), (C) are block diagrams of the head positioning control of the magnetic disk apparatus as the preferred embodiment of the present invention. In this figure, 11 denotes magnetic head consisting of a data head and a servo head; 12, voice coil motor for driving actuator loading magnetic heads; 13, amplifier; 14, DA converter; 15, position signal demodulating circuit; 16, AD converter; 17, counter; 18, digital arithmetic circuit; 19, arithmetic circuit for addition, subtraction, multiplication and division; 20, memory; 20a, 20b, first and second data tables.

The arithmetic circuit 19 comprises, in a concrete example of Fig. 5(B), a circuit 190 for computing position of magnetic head, a circuit 191 for estimating speed of the head, a circuit 192 for normalizing the position signal, a circuit 193 for computing seek distance, a circuit 194 for computing the normalized time, a circuit 195 for computing the target velocity, a circuit 196 for computing the target acceleration, a switch circuit 197 for switching the normalized time signal, a circuit 198 for respectively computing the gains of target velocity and the target acceleration, a circuit 199 for computing error signal between the current velocity and target velocity and a circuit 200 for adding the velocity error signal and target acceleration

signal.

The current position of magnetic head on the magnetic disk can be obtained by the position computing circuit 190 using the accumulated value of track pulse obtained from a counter 17 and deviation from the track center of magnetic head obtained from an AD converter 16. In this case, head velocity can be obtained by inputting the current position signal and a drive signal of voice coil motor to the velocity estimation circuit 191 and then computing such input signals with the ordinary velocity estimation algorithm for general purpose. Such velocity estimation algorithm is described, for example, in "Digital Control of Dynamic Systems", 2nd edition, Addison-Wesley, 1990, pp. 703-749 by G. Franklin, J. Powell and M.L. Workman.

The current position signal (current track position) thus obtained is input to the seek distance arithmetic circuit 193 which computes difference between the current track and the target track designated from the host controller. However, this seek distance a is computed at the time of starting the seek operation and is constant during the seek operation. Relationship between this seek distance a and the designet seek time T is preset and stored, for example, in the first data table 20a. In this case, the gains (A,B in the figure) of the target velocity and the target acceleration of equation (8) explained above can be obtained only with multiplication conducted in the gain arithmetic circuit 198 by storing the inverse number 1/T of the designed seek time T to table 20a. A ratio Ts/T of the sample period Ts and designed seek time T can also be stored in the first data table 20a. Meanwhile, the second data table 20b is capable ofid storing relationship between the normalized time (t/T) and normalized position (X/a).

As explained above, the cost function J may be expressed by the following equation.

$$J = \int_0^T u^2 \, dt$$

Where, u = di/dt and the drive current i is proportional to the acceleration. Therefore, the cost function J becomes equal to a value obtained by integrating the square value of the differential value of acceleration.

The target position X_1, target velocity X_2 and target acceleration X_3 for positioning control which minimizes the cost function J are respectively indicated by the expressions of fifth, fourth and third orders. For instance, when constants are assumed as C_0 C_4, the target velocity X_2 is indicated as follows.

$$X_2 = C_4 (t/T)^4 + C_3 (t/T)^3 + C_2 (t/T)^2 + C_1 (t/T) + C_0$$

Such equations of target position, target velocity and target acceleration may be solved as indicated by the equations (5), (6) and (7) with the boundary conditions of $X_1 = a$, $x_2 = 0$, $X_3 = 0$ for $t = 0$ and $X_1 = 0$, $X_2 = 0$ and $X_3 = 0$ for $t = T$.

The arithmetic circuits 196, 197 obtain the target velocity X_2 and target acceleration X_3 for each sample period using the equations (6), (7), (8) and outputs a drive output signal to cause the magnetic head 11 to follow such states. The arithmetic processing may be simplified by retrieving the first and second data tables 20a, 20b in the arithmetic process.

The normalized time t/T explained above may be determined by a couple of methods during the seek operation in the present invention. In the one method, it is determined by the arithmetic circuit 194 explained above. In this case, t/T is computed using 1/T which is an output of the first data table 20a and the clock of digital arithmetic circuit. In the other method, the second data table 20b is used. Here, the second data table stores the relationship between the normalized position X/a and normalized time t/T and outputs the normalized time t/T from the normalized position X/a obtained by the position signal normalizing circuit 192 explained above.

For the target acceleration arithmetic circuit 196, the normalized time t/T output from the arithmetic circuit 194 is used. Moreover, for the target velocity arithmetic circuit 195, two kinds of normalized times explained above are selectively used. Namely, the normalized time t/T output from the arithmetic circuit 194 is used for acceleration mode of seek operation while the normalized time t/T stored in the second data table 20b is used for the deceleration mode. The switch circuit 197 is used for switching use of the normalized times.

Moreover, in case Ts/T for seek distance a is stored in the first data table 20a, t/T of each sample period can be obtained only by accumulating the values read from the first data table 20a.

Moreover, in case the relationship between the normalized time t/T and normalized position X/a is stored in the second data table 20b, the current distance X is divided by the seek distance a for each sample period and the normalized time t/T can be obtained from the second data table 20a based on such value X/a (normalized position). Accordingly, the target position X_1, target velocity X_2 and target acceleration X_3 can be computed using such normalized time t/T for each sample period.

The drive signal for the voice coil motor 12 of actuator is obtained from an adder circuit 200 for adding an output (FF signal) of the target acceleration arithmetic circuit 196 and an output of an error signal arithmetic circuit 199. In this case, the error signal arithmetic circuit 199 obtains difference between an output (target velocity) of the target velocity arithmetic circuit 195 and an output (current velocity) of the velocity estimation circuit 192 and outputs a velocity error signal.

For instance, an inverse value 1/T of the seek time T is obtained on the basis of seek distance a immediately before (at the time of starting) the seek operation, the gains ($-60a/T$, $-60a/T^2$) of target velocity and target acceleration of equation (8) are computed, the normalized time t/T in the equations (5) (7) is computed for each sample time by multiplying the time passage t after start of seek time the inverse value 1/T of the seek time, and the target position X_1, target X_2 and target acceleration X_3 can be computed trough multiplication of constants based on such values.

This motor drive signal is then converted to an analog signal, namely to the drive current by the DA converter 14. This drive current is amplified by an amplifier 13 and is then supplied to the voice coil motor 12. Thereby, the voice coil motor 12 is driven and the magnetic head 11 is positioned to the target track.

The digital arithmetic circuit 18 may be formed by a digital signal processor including a multiplier. An external memory is also provided and thereby the first and second data tables 20a, 20b can also be formed.

Fig. 6 is a flowchart for explaining operations of preferred embodiment. This flowchart indicates 16 processing steps (1) (16) in the digital arithmetic circuit 18. In the first step (1), the target speed gain and target acceleration gain (FF feed forward gain) are computed with the equation (8) by start of seek operation. In this case, since the seek distance a can be detected from the number of tracks which is equal to difference between the current track position and the target track position of the magnetic head 11, the designed seek time T or its inverse number 1/T is obtained by retrieving the first data table 20a and the target velocity gain and target acceleration gain can be computed using this value 1/T.

In the step (2), the current position information of head 11 is input for each sample period and in the step (3), the acceleration period or deceleration period is decided. This decision is based on the current position information and the former half section from the boundary which is equal to 1/2 of the seek distance a is set as the acceleration section, while the latter half section as the deceleration section.

In the case of acceleration section, t/T is computed in the step (4) and the target velocity is computed by the equation (6) in the step (5). Moreover, the target acceleration signal (Feed Forward FF signal) is computed by the equation (7) in the step (10), estimated velocity value (actual velocity of head) is computed in the step (11), velocity error = target velocity - estimated velocity value is computed in the step (12) and output signal = velocity error + FF signal is computed in the step (13). In the next step (14), the actuator drive signal is output to the amplifier 13 and the drive current is supplied to the voice coil motor 12 from the amplifier 13. Thereafter, end of seek operation is decided in the step (15). If seek is not completed, operation skips to the step (2). When seek is completed, the tracking control of step (16) starts.

On the other hand, in the deceleration period, X/a is computed in the step (6) and the normalized time t/T is retrieved from the second data table based on the normalized position X/a in the step (7). The target speed is computed by the equation (6) in the step (8) based on such data and operation skips to the step (10).

In the arithmetic circuit of Fig. 5(B) explained above, only the target velocity is used as the embodiment but the present invention is not limited only to such embodiment. That is, the target position can also be used in addition to such target velocity and only the target position may also be used. Fig 5(C) shows a block diagram of the arithmetic circuit when both target velocity and target position are used. The arithmetic circuit of Fig. 5(C) is different from that of Fig. 5(B) in such points that an arithmetic circuit 201 for computing the target position is added and the gain arithmetic circuit 198 is also used to compute the gain (C in the figure) of the target position. Therefore, in this case, the error signal arithmetic circuit 199 respectively computes error between the target velocity and current velocity and error between the target position and current position and input these error signals to the adder circuit 200. Moreover the adder circuit 200 adds this position error signal, velocity error signal and target acceleration signal and the added signal of these is used as the voice coil motor drive signal.

Fig. 7 is a diagram for explaining normalized position, velocity and acceleration of magnetic head. In this diagram, the normalized time t/T is plotted on the horizontal axis, while the normalized position X/a, normalized velocity and normalized acceleration on the vertical axis, respectively. The curve a1 indicates

the target normalized position; the curve a2, the target normalized velocity and the curve a3, the target normalized acceleration.

Namely, the seek operation of magnetic head is completed at the normalized time $t/T = 1$. Therefore, the acceleration time is set in the range 0 0.5 of normalized time t/T and the deceleration time is set in the range 0.5 1 of t/T. The maximum normalizing acceleration in the acceleration period is generated at the normalized time $t/T = (3 - \sqrt{3})/6$.

Fig. 8 shows relationship between the seek distance a of the magnetic head and inverse number $1/T$ of designed seek time T with a curve b. The seek distance a corresponds to a number of tracks which is equal to difference between the current track and the target track of the magnetic head 11. When the seek distance a is given, the inverse number $1/T$ of the designed seek time can be obtained by looking up such relationship in the first data table 20a. Therefore, the target velocity gain, target acceleration gain and normalized time t/T can easily be obtained.

Fig. 9 indicates relationship between the normalized distance X/a and normalized time t/T. The acceleration period is set in the range 0 0.5 of the normalized time t/T, while the deceleration period in the range 0.5 1.0 of t/T. Accordingly, in the acceleration period, the normalized distance X/a is ranged from 0 to 0.5, while it is ranged from 0.5 to 1 in the deceleration period. The normalized time t/T may be obtained from the normalized distance X/a in each sample period by looking up such relationship in the second data table 20b. Therefore, the target position, target velocity and target acceleration can easily be computed.

Fig. 10 is a diagram indicating the acceleration characteristic of magnetic head. The vertical axis indicates acceleration m/s^2 and horizontal axis indicates time ms . The curve a shows an example of acceleration characteristic by the embodiment of the present invention and the curve b shows acceleration characteristic of the prior art. In case the positioning of magnetic head is completed within the period of about 5 ms, the embodiment of the present invention realizes smooth positioning control of magnetic head since the peak value of acceleration is smaller than that of prior art and it also changes more smoothly.

According to the embodiment of the present invention, the velocity and acceleration control may be realized for actuator without derivation of vibration of magnetic head. Moreover, the magnetic head can also be positioned to the target track accurately at a high speed. Moreover, such positioning control may also be executed with simplified algorithm by digital arithmetics.

A preferred embodiment applied to the magnetic disk apparatus has been explained above, but moreover the present invention can also be applied to positioning control of optical head of disk apparatus and that of print head of printer. In addition, this embodiment can surely be applied to mechanical positioning of an object to be controlled to the target position.

The embodiment of present invention will be limited only by the scope of the claim thereof.

Claims

1. A system for positioning a control object (1) to a designated target position comprising drive means (2)-for moving and positioning said control object(1)and arithmetic control means (3) for controlling said drive means (2) based on the result of digital arithmetics; wherein target position, target velocity and target acceleration are indicated with polynomials of time based on acceleration and deceleration patterns which minimize the square value of the differential value of acceleration of said control object-(1); and wherein said arithmetic control means (3)compute target position, target velocity and target acceleration of each sample period using such polynomials, output at least one error between the target position, target velocity as a result of arithmetic and position, velocity of each sample period of said control object (1),control said drive means (2)by means of a composite signal of such position error or velocity error and the target acceleration as a result of arithmetic and thereby position said control object (1).

2. A system for positioning a control object according to claim 1, wherein said target position is assumed as X_1, said target velocity as X_2, said target acceleration as X_3, seek distance as a, designed seek time as T and polynomials regarding time as

$$X_1 = -60a\ 0.1(t/T)^5 - 0.25(t/T)^4 + (1/6)(t/T)^3$$
$$X_2 = -60a\ 0.5(t/T)^4 - (t/T)^3 + 0.5(t/T)^2\ /T$$
$$X_3 = -60a\ 2(t/T)^3 - 3(t/T)^2 + (t/T)\ /T^2$$

and the target position X_1, target velocity X_2 and target acceleration X_3 for each sample period are computed in said arithmetic control means (3).

3. A system for positioning a control object according to claim 2, wherein a data table (4)storing the data indicating the designed seek time T corresponding to the seek distance a of said control object(1)or the inverse of said designed seek time T or the ratio of said designed seek time T and sample period is provided and the target velocity gain and target acceleration gain are decided using the numerical data obtained by retrieving said data table (4) .

4. A system for positioning a control object according to claim 2 oder 3, wherein the period from start to end of positioning of said control object (1)is normalized by said designed seek time T for each sample period in said arithmetic control means (3) said target acceleration is computed using said normalized time, said target acceleration is multiplied with said target acceleration gain and said result of multiplication is applied to the drive signal to be supplied to said drive means (2).

5. A system for positioning a control object according to anyone of claims 2 to 4, wherein a data table storing the data which indicates said normalized time and normalized position is provided and said target position, target velocity and target acceleration are computed by computing said normalized position from the current position and seek distance a of said control object(1)and said normalized time is obtained by retrieving said table (4)with said normalized position.

6. A system for positioning a control object according to anyone of claims 1 to 5, wherein said control object(1)is composed of a magnetic head which is movable on a magnetic disk and said drive means-(2)is composed of an actuator loading a magnetic head and a positioning motor for driving said actuator.

7. A system for positioning a control object according to anyone of claims 1 to 5, wherein said control object(1)is composed of an optical head which is movable on an optical disk and said drive means(2)is composed of an actuator loading an optical head and a positioning motor for driving said actuator.

8. A system for positioning a control object according to anyone of claims 1 to 5, wherein said control object (1)is composed of a print head which is movable on a printing sheet and said drive means(2)is composed of an actuator loading a print head and a positioning motor for driving said actuator.

9. A system for positioning a magnetic disk apparatus consisting of an actuator for moving and positioning a magnetic head (11)to the designated track on a magnetic disk and an arithmetic control means (17,18,19,20)for controlling a drive motor (12)of said actuator based on result of digital arithmetics; wherein said arithmetic control means (17,18,19,20)comprises;

three arithmetic circuits (190,195,196)for respectively computing the target position, target velocity and target acceleration of each sample period with polynomials of time of the target position, target velocity and target acceleration generated based on the acceleration and deceleration patterns which minimize square value of the differential value of the acceleration of said magnetic head (11),

two arithmetic circuits (191)for estimating position and velocity of each sample time of said magnetic head,

a sixth arithmetic circuit (199)for computing at least one error between the target position, target velocity output from said first and second arithmetic circuits and position, velocity output from said fourth and fifth arithmetic circuits, and

a seventh arithmetic circuit (200)for adding the target acceleration signal output from said third arithmetic circuit and the position error output from the fourth arithmetic circuit or velocity error signal output from the fifth arithmetic circuit and then outputting a control signal for the drive motor(12)of said actuator.

10. A system for positioning a control object comprising a driver for moving and positioning a control object(1;11)and a controller (3;18)having a means for generating at least one of the target acceleration, target velocity and target position and controlling said driver in accordance with at least one error of position, velocity and acceleration of control object measured or estimated from said control object, characterized in that the differential value of acceleration of said control object(1;11)is continuous and is less than the predetermined constant value during the seek operation and that the positioning is carried out using the target acceleration where the changing rate does not exceed predetermined constant value.

11. A system for positioning a control object according to claim 10, wherein the target acceleration, target velocity and target position are expressed by the function for normalized time (t/T), $F = \Sigma a_i (t/T)^m$ using the value (t/T) obtained by normalizing the time t from start to end of the seek operation of the control object(1;11) with the designed seek time T and these functions are used.

FIG. 1 (PRIOR ART)

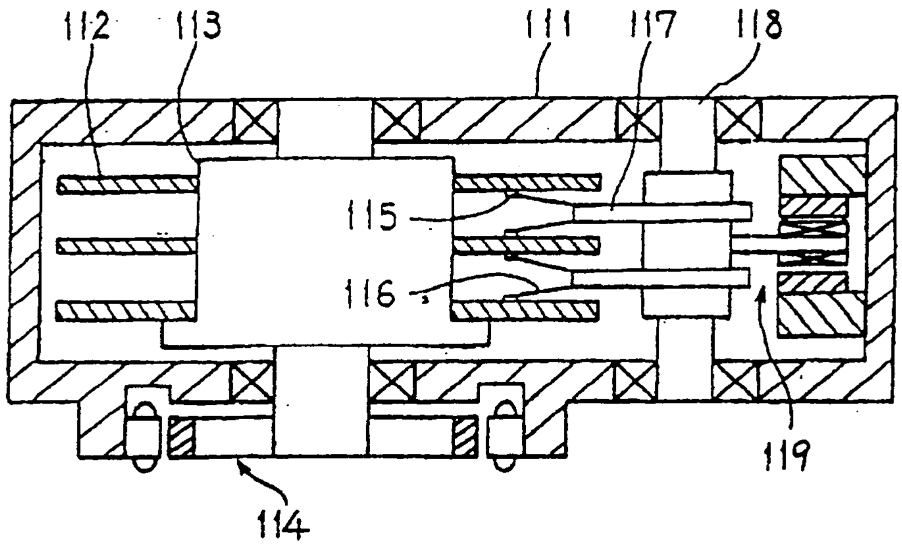


FIG. 2 (PRIOR ART)

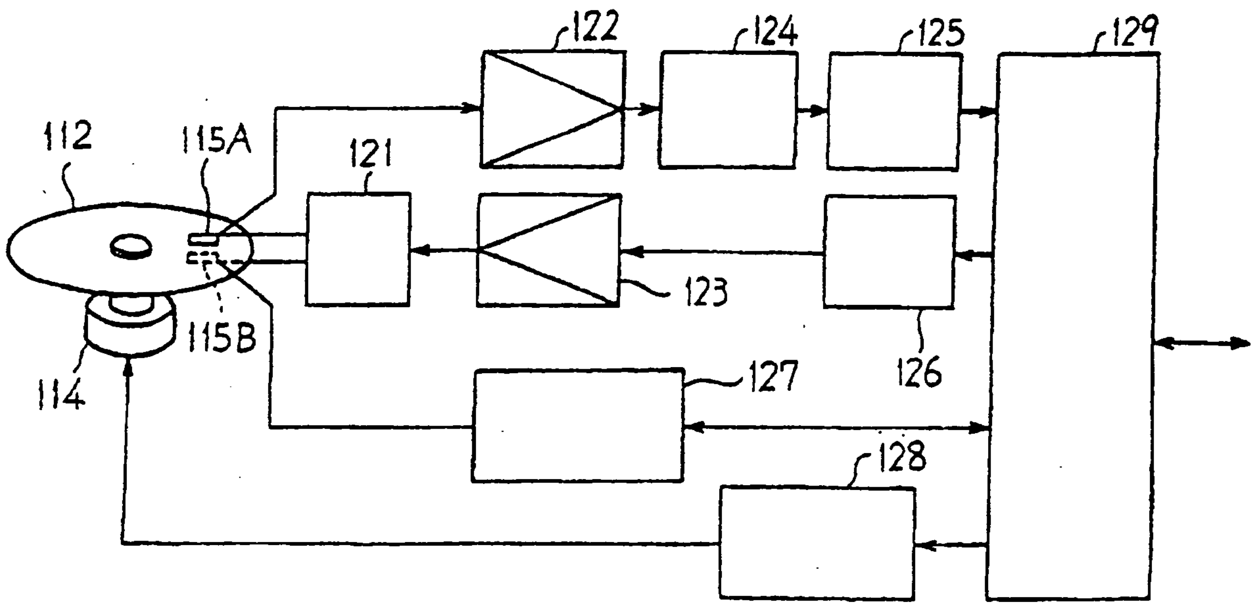


FIG. 3 (PRIOR ART)

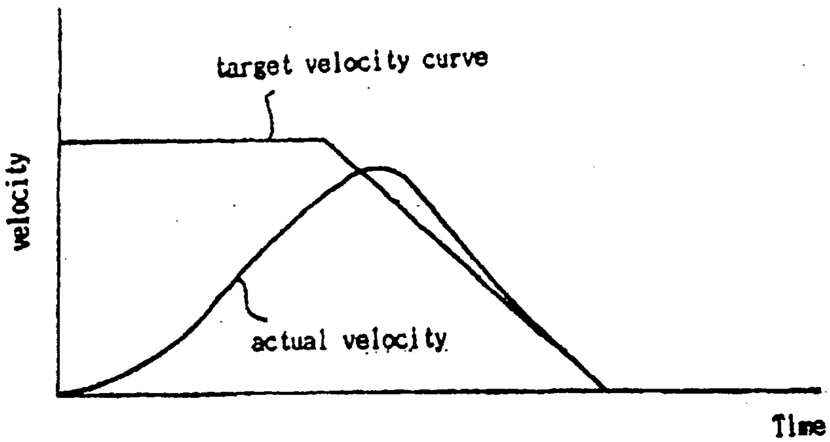


FIG. 4

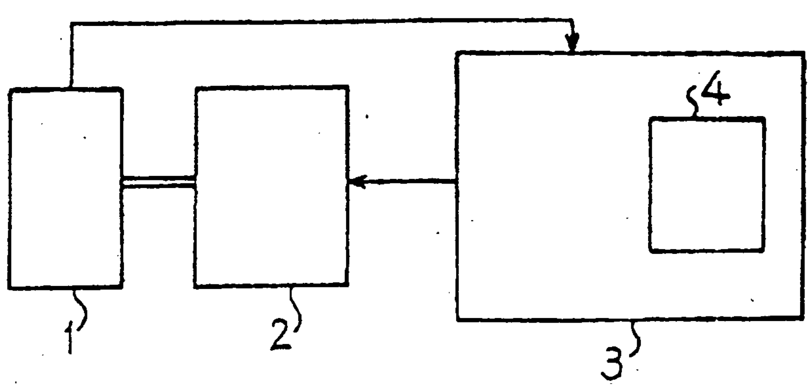


FIG. 5(A)

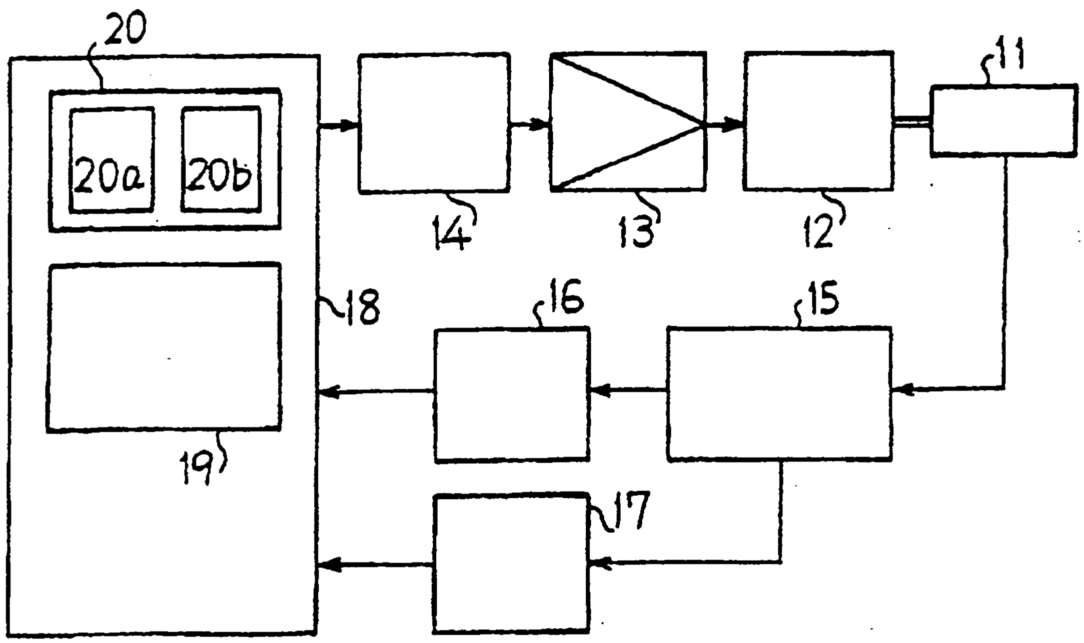


FIG. 5(B)

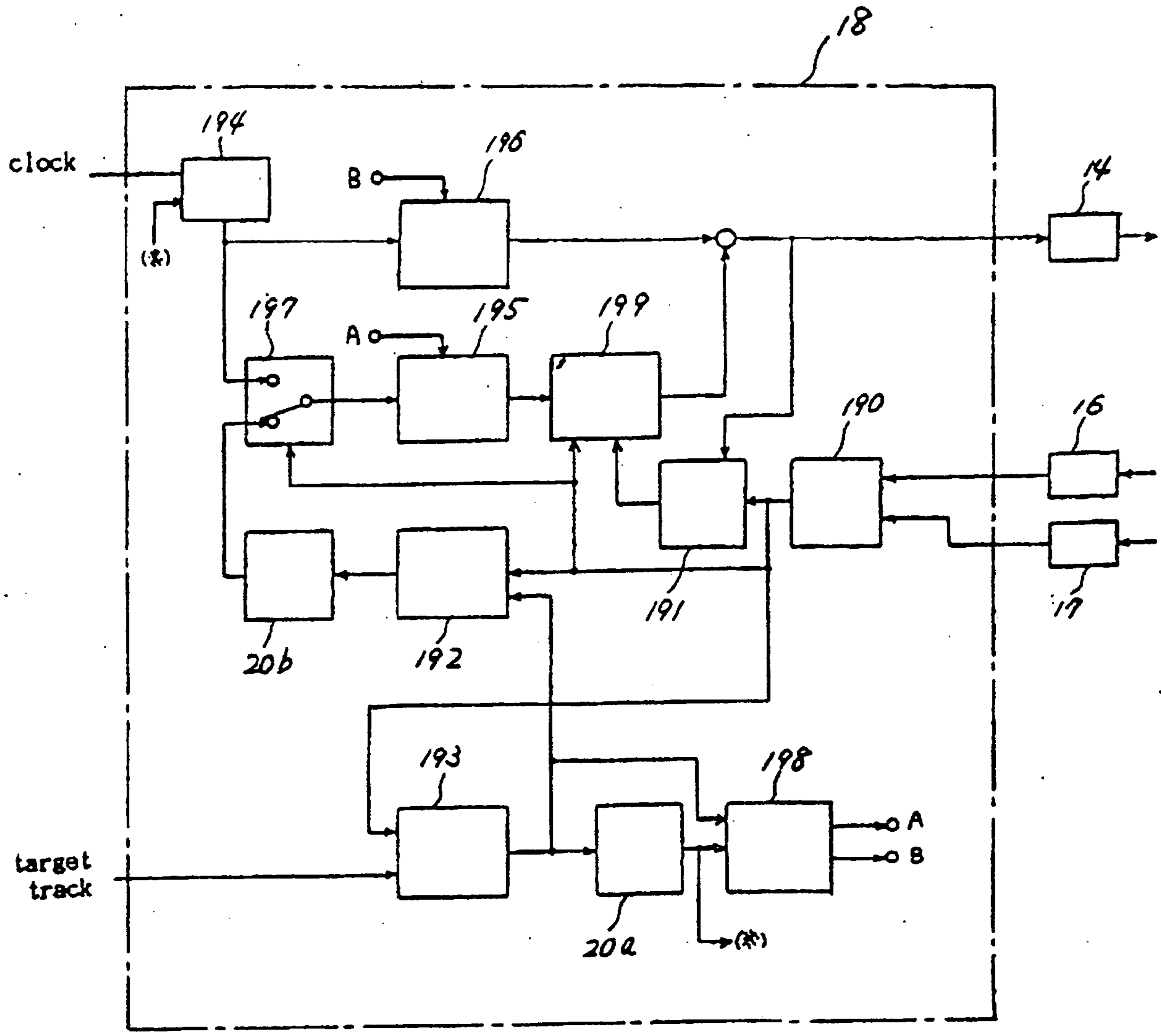

18
194
196
clock
B
(※)
14
197
195
199
A
190
16
191
17
20b
192
193
198
A
B
target
track
20a
(※)

FIG. 5(c)

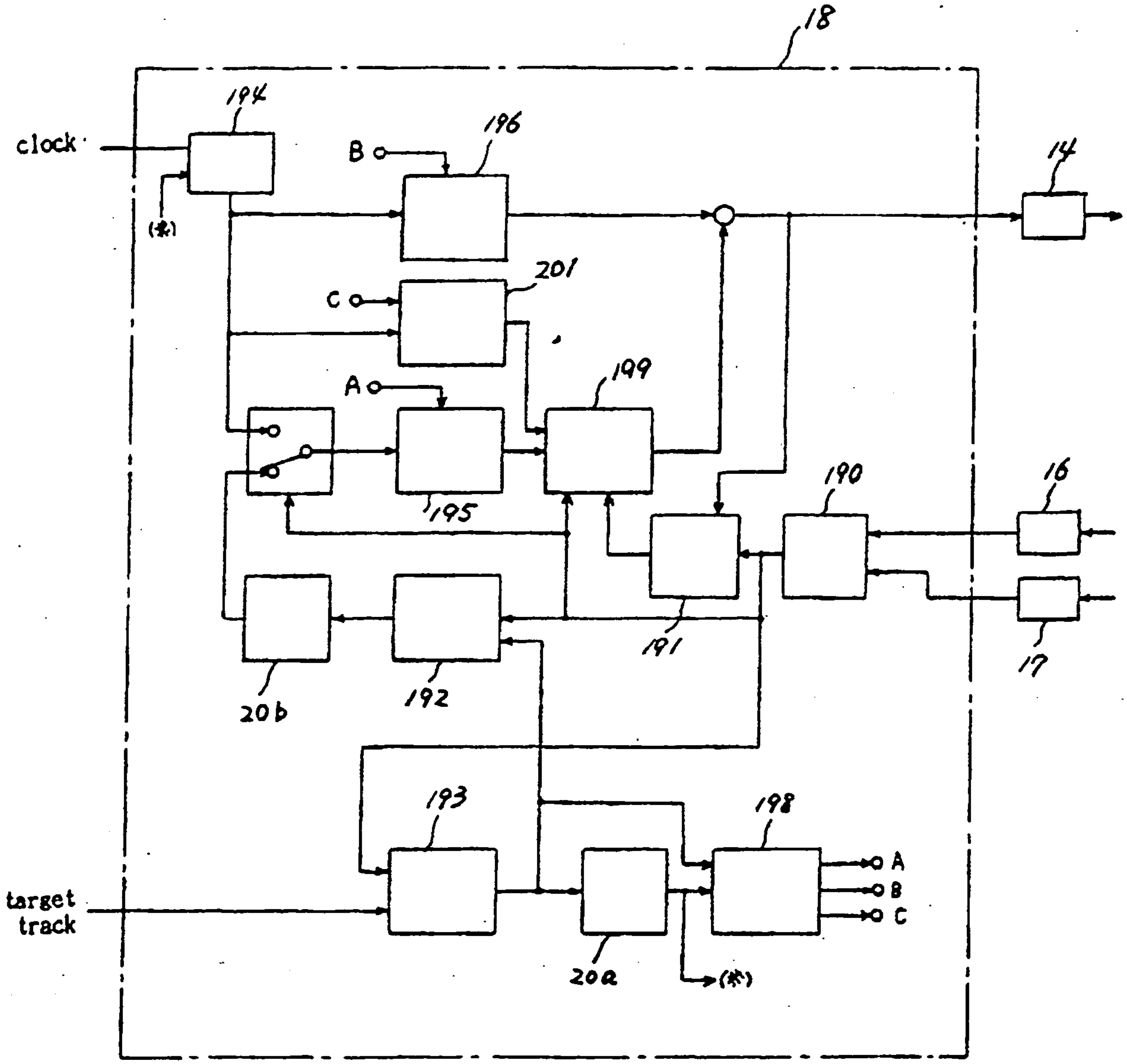
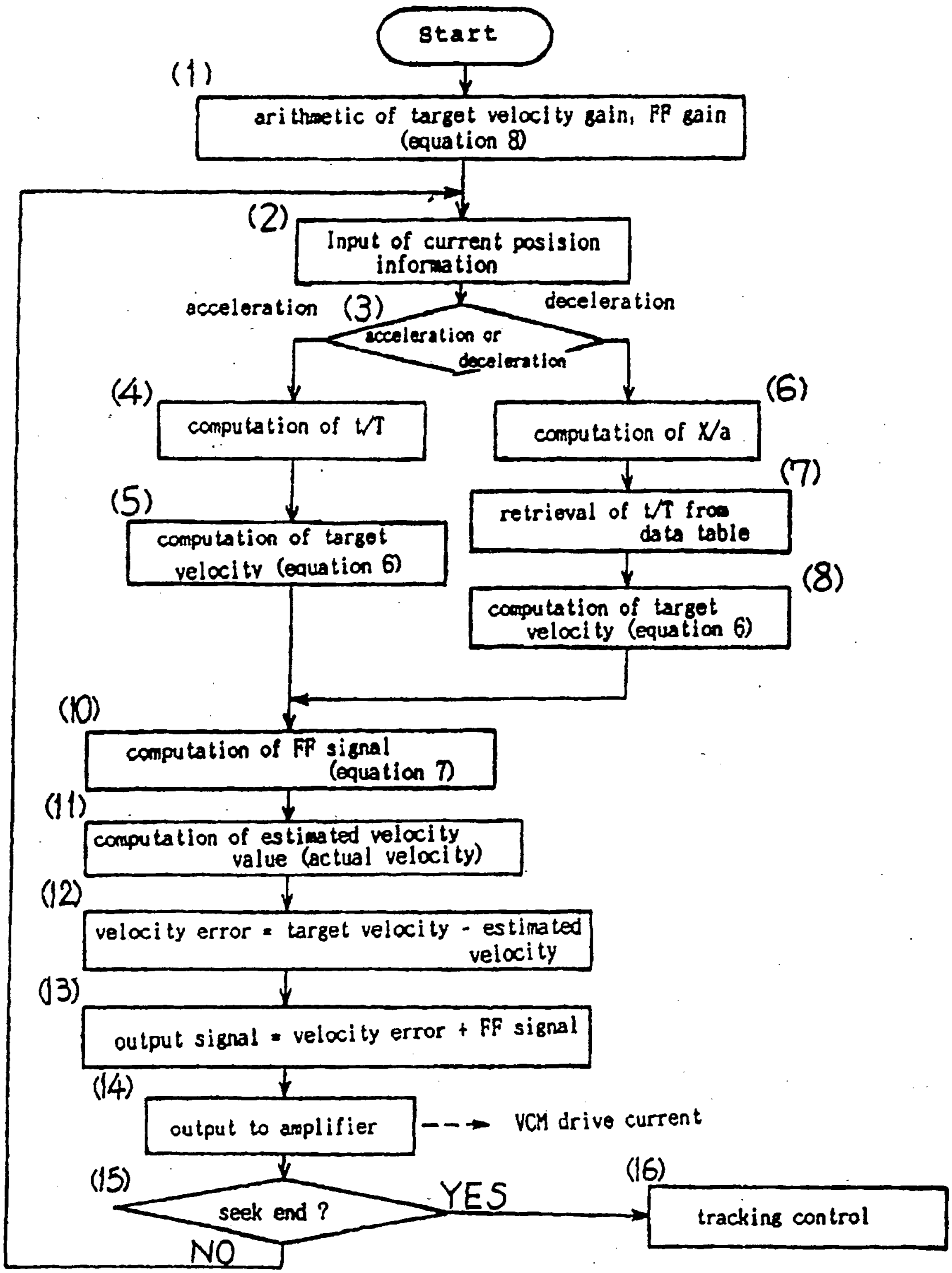
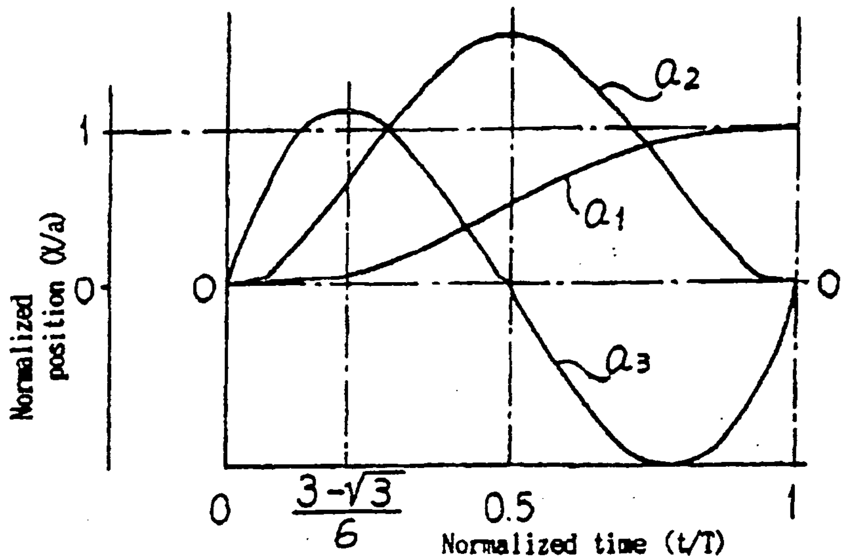

18
194
196
B
clock
(*)
14
201
C
199
A
190
16
195
191
17
20b
192
193
198
A
B
C
target
track
20a
(*)

FIG. 6


Start
(1)
arithmetic of target velocity gain, FF gain (equation 8)
(2)
Input of current posision information
acceleration
(3)
acceleration or deceleration
deceleration
(4)
computation of t/T
(5)
computation of target velocity (equation 6)
(6)
computation of X/a
(7)
retrieval of t/T from data table
(8)
computation of target velocity (equation 6)
(10)
computation of FF signal (equation 7)
(11)
computation of estimated velocity value (actual velocity)
(12)
velocity error = target velocity - estimated velocity
(13)
output signal = velocity error + FF signal
(14)
output to amplifier
VCM drive current
(15)
seek end ?
YES
NO
(16)
tracking control

F I G . 7


a2
1
a1
Normalized position (X/a)
0
0
0
a3
0
$\frac{3-\sqrt{3}}{6}$
0.5
1
Normalized time (t/T)

F I G . 8

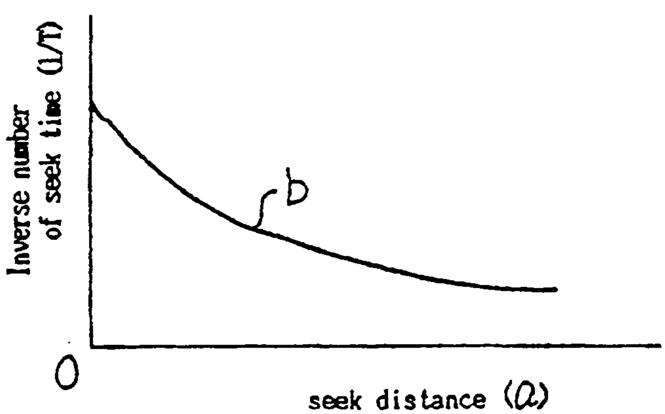

Inverse number of seek time (1/T)
b
0
seek distance (Q)

FIG. 9

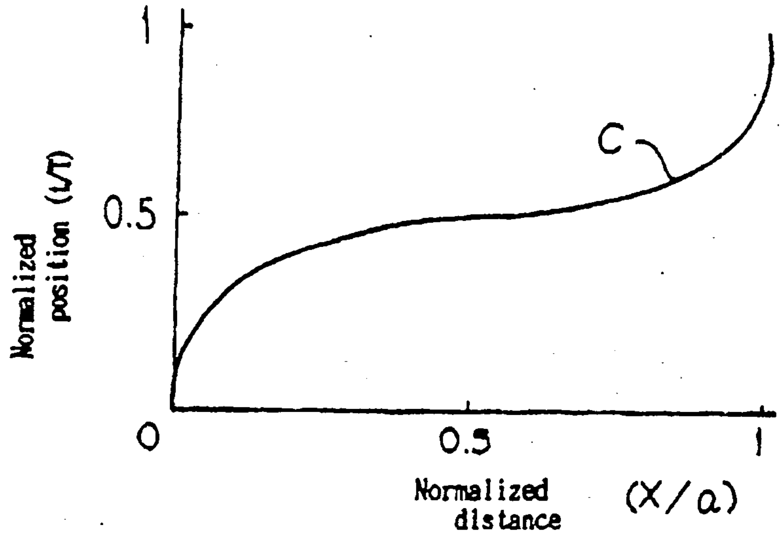
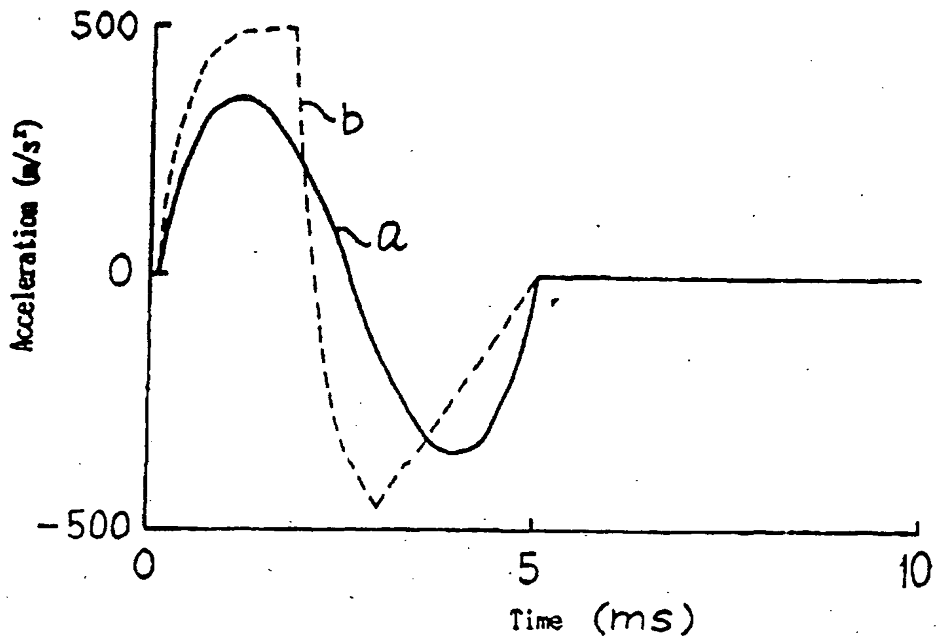

1
0.5
0
0.5
1
C
Normalized position (L/T)
Normalized distance (X/a)

FIG. 10


500
0
-500
0
5
10
b
a
Acceleration (m/s²)
Time (ms)